Coastal Engineering Technical Note

AUTOMATED COASTAL ENGINEERING SYSTEM

Version 1.07

PURPOSE

This note discusses a microcomputer-based software package that contains reliable state-of-the-art solutions to various coastal engineering problems.

BACKGROUND

In 1986 the Coastal Engineering Research Center (CERC) recommended to the Office, Chief of Engineers that an Automated Coastal Engineering System (ACES) be developed to give Corps offices an interactive computer based design capability in the field of coastal engineering. The recommendation was in response to a charge by the Chief of Engineers, LTG E. R. Heiberg III, to the Coastal Engineering Research Board to provide improved design capabilities to Corps coastal specialists.

CERC formed an internal technical committee to develop recommendations for implementing an automated design System. This committee obtained input from Corps field offices regarding the form and development procedures preferred for the system. The information was obtained primarily from six regional workshops conducted in July 1986 and attended by more than one hundred coastal specialists.

Based on recommendations from the workshops, a Pilot Committee composed primarily of Corps District and Division coastal specialists was formed in September 1986 to guide development of the ACES. In addition an Automated Coastal Engineering Group was formed in February 1987 within CERC to implement its development.

INTRODUCTION

The ACES is a microcomputer-based design and analysis system in the field of coastal engineering. The contents range from simple algebraic expressions both theoretical and empirical in origin, to numerically intense algorithms spawned by the increasing power and affordability of computers. The methods in the ACES range from classical theory describing wave motion, to expressions resulting from tests with structures in wave flumes, and to recent numerical models describing the exchange of energy from the atmosphere to the sea surface.

ACES CONTENTS

The various methodologies included in ACES are called **applications**, and are organized into categories called **functional areas** differentiated according to general relevant physical processes and design or analysis activities. A summary of the applications currently resident in the ACES is given in Table 1.

TABLE 1

Current ACES Applications (Version 1.07)	
Functional Area	**Application Name**
Wave Prediction	Windspeed Adjustment and Wave Growth
	Beta-Rayleigh Distribution
	Extremal Significant Wave Height Analysis
	Constituent Tide Record Generation
Wave Theory	Linear Wave Theory
	Cnoidal Wave Theory
	Fourier Series Wave Theory
Wave Transformation	Linear Wave Theory with Snell's Law
	Irregular Wave Transformation (Goda's method)
	Combined Diffraction and Reflection by a Vertical Wedge
Structural Design	Breakwater Design Using Hudson and Related Equations
	Toe Protection Design
	Nonbreaking Wave Forces on Vertical Walls
	Rubble-Mound Revetment Design
Wave Runup, Transmission, and Overtopping	Irregular Wave Runup on Beaches
	Wave Runup and Overtopping on Impermeable Structures
	Wave Transmission on Impermeable Structures
	Wave Transmission Through Permeable Structures
Littoral Processes	Longshore Sediment Transport
	Numerical Simulation of Time-Dependent Beach and Dune Erosion
	Calculation of Composite Grain-Size Distribution
	Beach Nourishment Overfill Ratio and Volume
Inlet Processes	A Spatially Integrated Numerical Model for Inlet Hydraulics

DESCRIPTION OF ACES APPLICATIONS

The various applications within the functional areas represent a number of different methodologies of varying complexity. A brief description of each application follows.

WAVE PREDICTION FUNCTIONAL AREA

Windspeed Adjustment and Wave Growth

The methodologies represented in this ACES application provide quick and simple estimates for wave growth over open-water and restricted fetches in deep and shallow water. Also, improved methods (over those given in the Shore Protection Manual (SPM), 1984) are included for adjusting the observed winds to those required by wave growth formulas.

Beta-Rayleigh Distribution

This application provides a statistical representation for a shallow water wave height distribution. The Beta-Rayleigh distribution is expressed in familiar wave parameters: H_{mo} (energy based wave height), T_p (peak spectral wave period), and d (water depth). After constructing the distribution, other statistically based wave height estimates such as H_{rms}, H_{mean}, $H_{1/10}$ can be easily computed. The Beta-Rayleigh distribution features a finite upper bound corresponding to the breaking wave height, and the expression collapses to the Rayleigh distribution in the deepwater limit. The methodology for this portion of the application is taken exclusively from Hughes and Borgman (1987).

Extremal Significant Wave Height Analysis

This application provides significant wave height estimates for various return periods. Confidence intervals are also provided. The approach developed by Goda (1988) is used to fit five candidate probability distributions to an input array of extreme significant wave heights. Candidate distribution functions are Fisher-Tippett Type I and Weibull with exponents ranging from 0.75 to 2.0. Goodness-of-fit information is provided for identifying the distributions which best match the input data.

Constituent Tide Record Generation

This application predicts a tide elevation record at a specific time and locale using known amplitudes and epochs for individual harmonic constituents.

WAVE THEORY FUNCTIONAL AREA

Linear Wave Theory

This application yields first-order approximations for various parameters of wave motion as predicted by the wave theory bearing the same name (also known as small amplitude, sinusoidal, or Airy theory). It provides estimates for engineering quantities such as water surface elevation, general wave properties, particle kinematics, and pressure as functions of wave height and period, water depth, and position in the waveform.

Cnoidal Wave Theory

This application yields various parameters of wave motion as predicted by first-order (Isobe, 1985) and second-order (Hardy and Kraus, 1987) approximations for cnoidal wave theory. It provides estimates for common items of interest such as water surface elevation, general wave properties, kinematics, and pressure as functions of wave height and period, water depth, and position in the waveform.

Fourier Series Wave Theory

This application yields various parameters for progressive waves of permanent form, as predicted by Fourier series approximation. It provides estimates for common engineering parameters such as water surface elevation, integral wave properties, and kinematics as functions of wave height, period, water depth, and position in the wave form which is assumed to exist on a uniform co-flowing current. Stokes first and second approximations for celerity (i.e., values of the mean Eulerian current or mean mass transport rate) may be specified. Fourier series of up to 25 terms may be selected to approximate the wave.

WAVE TRANSFORMATION FUNCTIONAL AREA

Linear Wave Theory with Snell's Law

This application provides a simple estimate for wave shoaling and refraction using Snell's law with wave properties predicted by linear wave theory. Given wave properties and a crest angle at a known depth, it predicts the values in deep water and at a subject location specified by a new water depth. An important assumption for this application is that all depth contours are assumed to be straight and parallel. The criteria of Singamsetti and Wind (1980) and Weggel (1972) are employed to provide an estimate for breaker parameters.

Irregular Wave Transformation (Goda's method)

This application yields cumulative probability distributions of wave heights as a field of irregular waves propagate from deep water through the surf zone. The application is based on two random-wave theories by Yoshimi Goda (1975 and 1984). The 1975 paper concerns transformation of random waves shoaling over a plane bottom with straight parallel contours. This analysis treated breaking and broken waves and resulted in cumulative probability distributions for wave heights given a water depth. It did not include refraction, however. The 1984 article details a refraction procedure for random waves propagating over a plane bottom with straight parallel contours assuming a particular incident spectrum. This ACES application combines the two approaches by treating directional random waves propagating over a plane bottom with straight parallel contours. This application also uses the theory of Shuto (1974) for the shoaling calculation. The theories assume a Rayleigh distribution of wave heights in the nearshore zone and a Bretschneider-Mitsuyasu incident directional spectrum. The processes modeled include: Wave refraction, Wave shoaling, Wave breaking, Wave setup, and Surf beat.

Combined Diffraction and Reflection by a Vertical Wedge

This application estimates wave height modification due to combined diffraction and reflection near jettied harbor entrances, quay walls, and other such structures. Jetties and breakwaters are approximated as a single straight, semi-infinite breakwater by setting the wedge angle to zero. Corners of docks and quay walls may be represented by setting the wedge angle equal to 90 degrees. Additionally, such natural diffracting and reflecting obstacles as rocky headlands can be approximated by setting a particular value for the wedge angle.

STRUCTURAL DESIGN FUNCTIONAL AREA

Breakwater Design Using Hudson and Related Equations

A rubble structure is often composed of several layers of random-shaped or random-placed stones, protected with a cover layer of selected armor units of either quarrystone or specially shaped concrete units. This ACES application provides estimates for the armor weight, minimum crest width, armor thickness, and the number of armor units per unit area of a breakwater using Hudson's and related equations. The material presented herein can be found in Chapter 7 of the SPM (1984).

Toe Protection Design

Toe protection consists of armor for the beach or bottom material fronting a structure to prevent wave scour. This application determines armor stone size and width of a toe protection apron for *vertical* faced structures such as seawalls, bulkheads, quay walls, breakwaters, and groins. Apron width is determined by the geotechnical and hydraulic guidelines specified in Engineer Manual 1110-2-1614. Stone size is determined by a method (Tanimoto, Yagyu, and Goda, 1982) whereby a stability equation is applied to a single rubble unit placed at a position equal to the width of the toe apron and subjected to standing waves.

Nonbreaking Wave Forces on Vertical Walls

This application provides the pressure distribution and resultant force and moment loading on a vertical wall caused by normally-incident, *nonbreaking*, regular waves. The results can be used to design vertical structures in protected or fetch-limited regions when the water depth at the structure is greater than about 1.5 times the maximum expected wave height. The application provides the same results as found using the design curves given in Chapter 7 of the SPM (1984).

Rubble-Mound Revetment Design

Quarrystone is the most commonly used material for protecting earth embankments from wave attack because, where high-quality stone is available, it provides a stable and unusually durable revetment armor material at relatively low cost. This ACES application provides estimates for revetment armor and bedding layer stone sizes, thicknesses, and gradation characteristics. Also calculated are two values of runup on the revetment, an expected extreme, and a conservative runup value.

WAVE RUNUP, TRANSMISSION, AND OVERTOPPING FUNCTIONAL AREA

Irregular Wave Runup on Beaches

This application provides an approach to calculate runup statistical parameters for wave runup on smooth slope linear beaches. To account for permeable and rough slope natural beaches, the present approach needs to be modified by multiplying the results for the smooth slope linear beaches by a reduction factor. However, there is no guidance for such a reduction due to the sparsity of good field data on wave runup. The approach used in this ACES application is based on existing laboratory data on irregular wave runup (Mase and Iwagaki, 1984 and Mase, 1989).

Wave Runup and Overtopping on Impermeable Structures

This application provides estimates of wave runup and overtopping on rough and smooth slope structures that are assumed to be impermeable. Run-up heights and overtopping rates are estimated independently or jointly for monochromatic or irregular waves specified at the toe of the structure. The empirical equations suggested by Ahrens and McCartney (1975), Ahrens and Titus (1985), and Ahrens and Burke (1987) are used to predict runup, and Weggel (1976) to predict overtopping. Irregular waves are represented by a significant wave height and are assumed to conform to a Rayleigh distribution (Ahrens, 1977). The overtopping rate is estimated by summing the overtopping contributions from individual runups in the distribution.

Wave Transmission on Impermeable Structures

This application provides estimates of wave runup and transmission on rough and smooth slope structures. It also addresses wave transmission over impermeable vertical walls and composite structures. In all cases, monochromatic waves are specified at the toe of a structure that is assumed to be impermeable. For sloped structures, a method suggested by Ahrens and Titus (1985) and Ahrens and Burke (1987) is used to predict runup, while the method of Cross and Sollitt (1971) as modified by Seelig (1980) is used to predict overtopping. For vertical wall and composite structures, a method proposed by Goda, Takeda, and Moriya (1967) and Goda (1969) is used to predict wave transmission.

Wave Transmission Through Permeable Structures

Porous rubble-mound structures consisting of quarry stones of various sizes often offer an attractive solution to the problem of protecting a harbor against wave action. It is important to assess the effectiveness of a given breakwater design by predicting the amount of wave energy transmitted by the structure. This application determines wave transmission coefficients and transmitted wave heights for permeable breakwaters with crest elevations at or above the still-water level. This application can be used with breakwaters armored with stone or artificial armor units. The application uses a method developed for predicting wave transmission by overtopping coefficients using the ratio of breakwater freeboard to wave runup (suggested by Cross and Sollitt, 1971). The wave transmission by overtopping prediction method is then combined with the model of wave reflection and wave transmission through permeable structures of Madsen and White (1976). Seelig (1979,1980) had developed a similar version for mainframe processors.

LITTORAL PROCESSES FUNCTIONAL AREA

Longshore Sediment Transport

This application provides estimates of the *potential* longshore transport rate under the action of waves. The method used is based on the empirical relationship between the Longshore component of wave energy flux entering the surf zone and the immersed weight of sand moved (Galvin, 1979). Two methods are available to the user depending on whether available input data are breaker wave height and direction or deepwater wave height and direction.

Numerical Simulation of Time-Dependent Beach and Dune Erosion

This application is a numerical beach and dune erosion model that predicts the evolution of an equilibrium beach profile from variations in water level and breaking wave height as occur during a storm. The model is one-dimensional (only onshore-offshore sediment transport is represented). It is based on the theory that an equilibrium profile results from uniform wave energy dissipation per unit volume of water in the surf zone. The general characteristics of the model are based on a model described by Kriebel (1982, 1984a, 1984b, 1986). Because of the complexity of this methodology and the input requirements, familiarization with the above references is strongly recommended.

Calculation of Composite Grain-Size Distributions

The major concern in the design of a sediment sampling plan for beach-fill purposes is determining the composite grain size characteristics of both the native beach and the potential borrow site. This application calculates a composite grain size distribution that reflects textural variability of the samples collected at the native beach or the potential borrow area.

Beach Nourishment Overfill Ratio and Volume

The methodologies represented in this ACES application provide two approaches to the planning and design of nourishment projects. The first approach is the calculation of the *overfill ratio*, which is defined as the volume of actual borrow material required to produce a unit volume of usable fill. The second approach is the calculation of a *renourishment factor* which is germane to the long-term maintenance of a project, and addresses the basic question of how often renourishment will be required if a particular borrow source is selected that is texturally different from the native beach sand.

INLET PROCESSES FUNCTIONAL AREA

A Spatially Integrated Numerical Model for Inlet Hydraulics

This application is a numerical model that estimates coastal inlet velocities, discharges, and bay levels as functions of time for a given time-dependent sea level fluctuation. Inlet hydraulics are predicted in this model by simultaneously solving the time-dependent momentum equation for flow in the inlet and the continuity equation relating the bay and sea levels to inlet discharge. The model is designed for cases where the bay water level fluctuates uniformly throughout the bay and the volume of water stored in the inlet between high and low water is negligible compared with the tidal prism of water that moves through the inlet and is stored in the bay. The model has been previously described by Seelig (1977) and Seelig, Harris, and Herchenroder (1977).

SYSTEM REQUIREMENTS

ACES is designed to run on IBM PC-AT (or compatible) machines with 640 Kb memory, a hard drive, and an 80287 math co-processor. The screen displays in ACES are designed in color. A color adaptor and monitor (EGA, PGA, or CGA) are preferable. Some monochrome display adaptors and monitors will also work. A printer is recommended, but not required. ACES is distributed on one **high density** diskette.

AVAILABILITY

Copies of version 1.07 may be obtained by forwarding a request to:

US Army Engineer Waterways Experiment Station
ATTN: CEWES-CR
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

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